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Abdominal mechanical scanner for the acoustic tomographic measurement of the visceral fat area
超音波トモグラフィ内臓脂肪測定のための腹部メカニカルスキャナ

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1. Introduction

The ultrasound tomography has been studied for the reconstruction of the abdominal sound speed image and to measure the visceral fat area.[1,2,3] The method is based on the travel time observations of the sound waves transmitted through the abdominal medium. For the realization of the system available at clinical trials, automatization of the measurement is indispensable for the sake of the technician power saving as well as shortening of the inspection time. In this paper, an open-air type abdominal body surface scanning machinery is developed, where a facing pair of broad band piezoelectric transmitter and receiver were mounted on the motor actuated stages. They are rotated along the circular ring, translated along the lateral direction, in addition, pushed along to-and-fro direction to keep close contact against the body surface. The amplitudes of the sound waves are monitored, so that the contact condition can be controlled at an optimal pushing position. It is also shown that measured precision of the sound travel time are good to reproduce the sound speed image in the human abdominal region.

2. Method

2.1 Structure of the automated body scanner

Automated body scanning machinery was developed, where a facing pair of transmitter (with frequency band 10-500 kHz and aperture diameter 40 mm) and receiver are mounted on the motor actuated stages. They are moved around the abdominal body according to the conventional translate and rotation scanning scheme. For instance, a pair of transmitter/receiver is translated along the lateral direction over the aperture width W=560 mm, and rotated along the circular ring with radius R=400 mm. At each observation position, the facing transducers are pushed along to-and-fro direction to keep the close contact against the body surface. Urethane gel hemi-spheres (diameter 80 mm, sound speed c_g= 1300 m/s) were attached in front of the transducers. The hemi-sphere coupling gel plays a role to maintain the good contact between the transducer and the body surface, regardless of the contact angle between them. The transmitter was excited by applying an high amplitude impulse voltage. The receiver transducer was connected to the reciever amplifier. The amplified singnals were digitized and transferred to the computer.

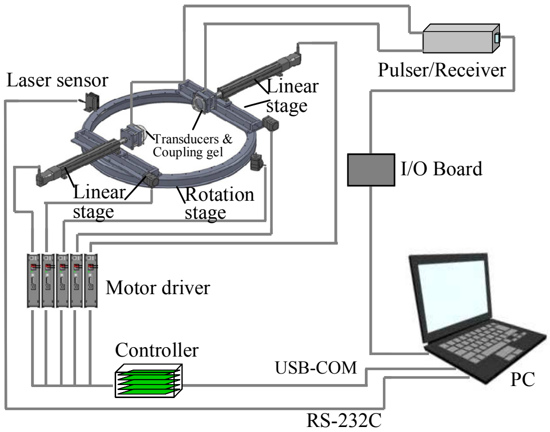

Fig.1 Body surface scanning machinery used in the experiment.

2.2 Strategy of detection and control of the contact status

For the realization of the automated body contact measurements, detection and control of the contact status is one of the key issue. To this end, contour of the body surface is measured by using the laser range sensor in advance as shown in Fig.2. Based on the information of the body surface

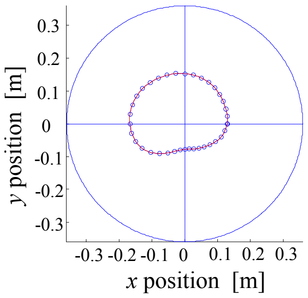

Fig.2 Measured body surface contour (circle: measured, red solid line: interpolated).

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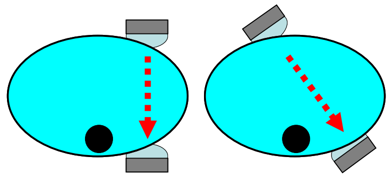
contour, the transducers are moved at the desired position on the body (alignment errors were less than 1mm). In order to keep the good contact between the body and the gel coupler, pushing distance is controlled by monitoring the amplitude of the received wave.

3. Test experiment

3.1 Phantom specimen

A urethane wall ultrasound abdominal phantom (275 x 200 mm) was prepared. As a background medium, ultrasound gel with sound speed c_0=1535 m/s was filled. In the interior region, a plastic spinal cord pillar (c_s=4000 m/s) was located. In addition, assuming a high sound speed abdominal muscle region and low sound speed visceral fat region, polyethylene glycol object with sound speed c_1=1610 m/s, low sound speed lard object with c_2=1450 m/s were located.



(a) Path-a (b)Path-b

Fig.3 Different contact condition between the body and coupling gel for (a) Path-a (parallel small contact angle), (b)Path-b (non-parallel large contact angle).

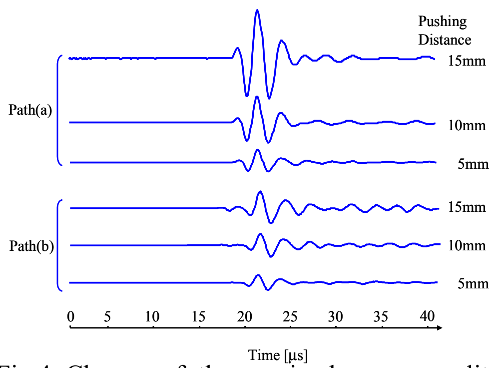


Fig.4 Change of the received wave amplitude with the advance of the pushing distance.

3.2 Detection of the contact status from the received wave amplitude

A facing pair of transducers was moved to the desired positions having different contact angles as shown in Fig.3. The variation of the received waves with the pushing distance for the observation position path-a and path-b are shown in Fig.4. The former path-a corresponds to the case for the small contact angle (parallel contact), on the other hand, latter for large contact angle (non-parallel contact). It is confirmed that the received sound wave amplitude can be used to monitor the contact status of the coupling gel to the body regardless of the contact angle condition.

3.3 Travel time measurement

Next, travel time difference data ΔT were measured with the variation of the pushing distance. Where, ΔT was obtained by subtracting the background travel time T_0 (=L/c_0, where L is the distance between the transducers and c_0 is the background sound speed) from that of the measurement specimens $T(=\int 1/c(\mathbf{x})d\mathbf{l}$, where $c(\boldsymbol{x})$ is the sound speed in the medium, $d\boldsymbol{l}$ is the propagation path element**)**. The results are shown in Fig.5. Each of the results are shown for different observation paths (path a and b in Fig.3). By comparison, theoretical values were shown. It can be recognized that the measured travel times are nearly constant over the wide range of the pushing distance. In addition, they are relatively in good agreement with the theoretical values. Some discrepancies (non-constant variation of the curve and deviation from the theory) are due to the effect of the sound propagation in the hemi-sphere coupling gel.

4. Conclusion

It was demonstrated that the automatic control of the transducer contact against the body surface and their high precision travel time measurements were successful. Accomplishment of the automated machinery is our on going work, examination results of the abdominal sound speed image will be nearly shown.

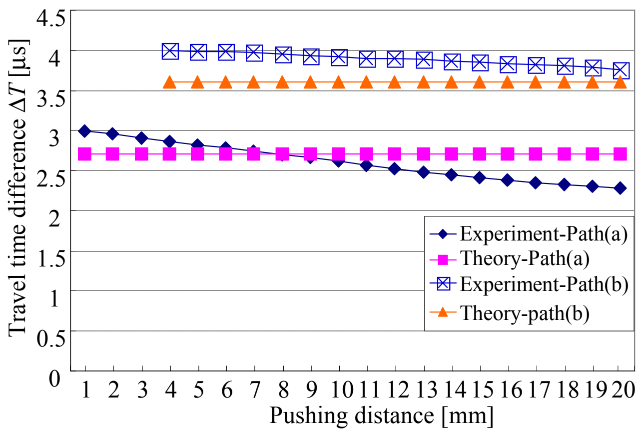


Fig.5 Relationship between the travel time and the pushing distance against the body surface.

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